LXI.—*On the Sacculi of the Polygastrica.* By JOHN WILLIAM GRIFFITH, M.D., F.L.S. &c.

To the Editors of the Annals of Natural History.

GENTLEMEN,

IF you will find a place in your valuable Journal for these observations on the Polygastric Animalcules, I shall feel obliged by your inserting them.

Your obedient servant,
JOHN WILLIAM GRIFFITH, M.D.

9 St. John's Square, May 8th, 1843.

The real nature of the sacculi, vesicles, or stomachs which are seen in the bodies of the Polygastric division of Infusorial Animalcules is a point which has occupied considerable attention, and is at the present time by no means satisfactorily determined. The extreme minuteness of these bodies renders their examination a matter of very considerable difficulty, and what has hitherto been discovered concerning their digestive cavities has been principally, if not entirely, recognized by the introduction of foreign colouring matters into the sacs; which colouring and other matters being moulded by the compressing force or elasticity of the containing sac or substance forming the walls of the cell in which they are contained, assume its shape, and are readily distinguished from the transparent parts of the animalcules by their opacity or altered refractive properties of light. Great difficulty is also experienced in conducting the manipulations which are required for examining such minute atoms, and an unusual share of patience and care. The rapidity of their movements is also, without extreme caution, liable to mislead the microscopic observer.

It is well known that when the animalcules denominated Polygastrica are examined under the microscope, certain sac-like bodies are observed in different parts of their bodies; these are sometimes filled with various coloured particles, similar to those floating in the water in which they live, sometimes merely with fluid or semifluid matters. These bodies, called by Prof. Ehrenberg stomachs, are variable in number and situation, and in some cases entirely absent.

An opinion that these sacculi were ova was formerly entertained by Gleichen, but this has long since fallen into disrepute; and justly so, inasmuch as the different matters which constitute the food of these minute animals has been, and can readily be, traced into the vesicles, which is sufficient to indicate their connexion with the digestive and not the reproductive system. The *Vorticellæ,* among many others, are particularly well adapted for the examination of these sacculi, on account of their large size, fixed position, or nearly so, and their great abundance.

Prof. Ehrenberg's view, that these vesicles are real stomachs or blind pouches leading out of an alimentary tube, is well known, and has been received for some time. It was founded upon the fact, that colouring and other matters upon which they feed, after having been drawn into the oral orifice of the canal, are next conducted to these cavities, where they remain a certain time; they are then propelled onwards, sometimes into other similar cavities, sometimes through the tract of the canal to the opposite extremity of the tube, whence either they or their undigested remains are expelled, or they are ejected by the same orifice at which they entered. Lately doubts have been thrown over these views, and many accurate observers are opposed to the doctrines of Ehrenberg. Having had considerable opportunities of observing these interesting objects under a great variety of conditions, I am convinced that the views of the different authors which I shall presently mention are each *generally* correct, and that with slight modifications they are readily reconcilable to one another. Professor Rymer Jones* says, "The positions of the mouth and anal aperture we are well assured by frequent examination to be such as are indicated by the illustrious Professor at Berlin; but with regard to the tube named by him intestine and the stomachs appended thereto, our utmost patient and long-continued efforts have failed to detect the arrangement depicted in his drawings. In the first place, as regards the function of the sacculi, which he looked upon as organs in which digestion is accomplished: in carnivorous animalcules which devour other species, we might expect, were these the stomachs, that the prey would be at once conveyed into one or other of these cavities; yet, setting aside the difficulty which must manifestly occur in lodging large animalcules in these microscopic sacs, and having recourse to the result of actual experience, we have never in a single instance seen an animalcule when swallowed placed in such a position, but have repeatedly traced the prey into what seemed a cavity excavated in the general parenchyma of the body. In the second place, the parenchyma has no appearance of being pedunculated, and consequently, in a certain degree fixed in definite positions: during the last two hours we have been carefully examining some beautiful specimens of *Paramecium aurelia*, an animalcule, which from its size is peculiarly adapted to the investigation of these vesicles; and so far from their having any appearance of connexion with a central canal, as represented in the figure copied from Ehrenberg, they are in continual circulation, moving slowly upwards along one side of the body, and in the opposite direction down the other, and resembling in every respect the coloured granules which have been described as visible in the gelatinous parenchyma of the *Hydra*. With respect to the central canal, we have not in any instance been able to detect it, or even any portion of the tube seen in the figures, much less the branches leading from it to the vesicles or stomachs, as they are called. Even the circumstances attending the prehension of food would lead us to imagine a different structure; witness, for example, the changes of form which *Enchelys pupa* undergoes when it devours an animalcule almost equal to itself in bulk, and is seen to assume a perfectly different shape as it dilates its mouth to receive the victim, with which its whole body becomes gradually distended. Such a capability of taking in and digesting a prey so disproportionate would in itself go far to prove that the minute sacculi were not stomachs, as it evidently cannot be in one of these that digestion is accomplished." Professor Jones then says he considers that there is an analogy between the organization of the so-named Polygastrica and of the *Hydra viridis*. He also says, "that the vesicles becoming coloured by the coloured food given to the animalcules cannot be considered as a proof of their being stomachs, as in the experiments of Trembley, the granules circulating in the body of the *Hydra* became dyed with the juices of the animals with which it was fed precisely in a similar manner."

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* 'A General Outline of the Animal Kingdom.' Although these views have been previously extracted into this Journal (vol. iii. p. 105.), as Professor Owen's observations obviously apply to some part of them, the subject would be incomplete without them.

M. Meyen says* he never admitted the observations of M. Ehrenberg, because in the first place "I never could see the intestines which form the communication between the stomachs, and likewise because I have observed, many years since, that the supposed stomachs were moving in the interior of the body of many species with great rapidity, in the same manner as the granules which circulate in the joints of the *Chara*. I have often seen *Vorticellæ* with nine or ten large globules of indigo in the belly, which always moved round a centre, and thus showed in the most evident manner that they could not have a communicating canal between the stomachs provided with an oral orifice and an extremity directed to the mouth." M. Meyen considers that the inner surface of the first part of the canal is provided with cilia, which roll up alimentary and colouring matters into the form of a ball. When the ball has acquired the size of the stomach, it is expelled by its other extremity and pushed into the cavity of the animal. If solid substances do not exist in the surrounding liquid, then the balls are less solid, and appear in the forms which they present in the Infusoria existing in colourless liquids. "In this case the balls are composed of a small number of particles, and principally of a considerable mucous mass which unites them."

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* Annals. of Nat. Hist. vol. iii. p. 100; also inserted in Pritchard's 'Gen. Hist. of Animalcules.'

The observations of Mons. Dujardin on this subject will be found in vol. iii. p. 170. of this Journal.

The objection (which M. Dujardin considers well-founded) advanced by M. Bory de St. Vincent, again presented by Dr. Foeke and Prof. Rymer Jones, the latter of whose words we have just quoted, rests on the inner motion of the globules or sacculi, which "can in no way be reconciled with the hypothesis of an intestine connecting all these globules together, and which, on the contrary, proves their entire independence." The reader will be able to estimate the validity of this objection when he has perused the remainder of this paper.

The following are the observations of Mr. Addison on this subject[*]:—"A singular fact[†] is stated with regard to the animalcules; it may be witnessed in all of them by the liquor potassæ. It penetrates the transparent tunic composing the body of the animalcule by imbibition, and soon causes it to burst open or explode, and the so-called stomachs of the creatures are forcibly discharged or thrown out one after another, thus becoming objects for minute microscopical scrutiny. The stomachs (?) swell and burst in like manner, precisely as the granules discharged from the lymph corpuscles of the frog. These stomachs he believes to be granulated vesicles performing their functions by imbibition, and not by assimilating or digesting food voluntarily taken. The vital powers of the animalcules are totally inefficient in opposing the imbibition of the poison, and their stomachs may be seen enlarging in the interior of the body prior to the rupture of the integument."

Dr. Carpenter says[‡], Ehrenberg's account of the numerous globular particles has been objected to by other observers, on the ground that these particles are seen to undergo a regular movement, as if they were floating in the midst of a fluid filling the general interior cavity of the body, and that they are sometimes discharged through the anal orifice. Of the validity of this objection his own observations have satisfied him. I cannot (says he) "doubt that these particles are cells which float in the fluid of the body, and elaborate the materials of its nutrition in the same manner as do those of the chyle and blood of higher animals."

Professor Owen's observations[§] answer some of the objections which have been raised to Ehrenberg's views. He says (speaking of the *Enchelys pupa* swallowing another animalcule nearly equal to itself in bulk, and thereby undergoing a total change in the form of its body), "but this may only imply great dilatability of the œsophagus or common canal, such as we observe in the boa constrictor, which becomes in like manner deformed after gorging a goat or other animal much thicker than itself; doubtless the little sacculi successively receive and digest, like the stomach of the boa, the dissolved parts of the swallowed prey. Then again it is objected that the sacculi are not fixed in definite positions, but are seen constantly, though slowly moving, and apparently rotating through the general cavity of the animal. But the peristaltic wave-like undulations of a common connecting canal, by drawing them successively in and out of focus of the observer, is quite sufficient, and very likely to occasion the deceptive appearance of their circulatory movements. If these stomachs were actually separate and closed sacs imbedded in the transparent gelatinous plasma of the animalcule and endowed with a circulatory movement, it is inconceivable that they should commonly present the characteristic arrangement which Ehrenberg has described and figured in particular species; as for example in the *Vorticella*, a circular arrangement, or the wavy disposition in *Leucophrys*; yet such a constancy in the arrangement of the assimilative sacs in these genera is the result of my experience. Add to this, if they have not orifices of communication with the alimentary tract, the difficulty of accounting for the rapid and ready transmission of the coloured aliment into their interior without the surrounding parenchyme being stained."

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[*] Prov. Med. and Surg. Journal, Aug. 20, 1842.

[†] These are not Mr. Addison's words, but an extract from his paper read before the British Association made by the editor of the journal.

[‡] Brit. and For. Med. Review, Jan. 1843.

[§] Hunterian Lectures, 1843.

In support of the views of Prof. Ehrenberg I refer the reader to vol. ii. p. 121. of the 'Annals,' wherein is contained an account of a discussion between this indefatigable observer and Prof. Jones. It will there be found that Ehrenberg considers the objection of Prof. Jones's not having been able to detect the stomachs in one or two instances as not sufficient to bring into doubt "the mass of relations which have been gradually established after many years of observation." Moreover, Prof. Ehrenberg says that *Paramecium Aurelia* is unfavourable to such observation, and that he himself has not been able to recognise the alimentary canal in all the species of the various genera. The Berlin Prof. says he had seen the circular motion of Prof. Jones, and states that "the great contractility of the body of the animalcules was, to less practised observers, not seldom a cause of enigmatical phænomena, of which continued patient observation of the object would gradually bring the explanation. Thus at times the intestinal canal of the animalcule extends at the expense of the ventral sacs so far, that it occupies the whole space of the body, and then the devoured substances, very similar to the ventral sacs, circulate in the whole body." He then gives three sketches of *Loxodes Bursaria*, wherein the first represents the animalcule in its ordinary state, with the alimentary canal and sacculi; the second, where the direction of particles in the alimentary canal is depicted; and the third, where the currents or motions of particles are indicated in the distended intestinal canal.

In addition to this, I refer to the Proceedings of the Royal Prussian Academy of Sciences at Berlin for Feb. 1841*, wherein is related an account of the observations of Dr. Werneck, which agree in support of those of Prof. Ehrenberg; nay, go further, for Dr. Werneck renders more probable than heretofore, that the alimentary canal exists in all the Polygastrica.

I extract the following observations from the report of Prof. Ehrenberg on Dr. Werneck's discoveries as made to the Academy: "Indeed what I, from caution, mentioned as only a supposition, viz. that probably even in the monads (*Bodo socialis*) a distinct anus, consequently an intestine, existed, whereby then the division of the *Anentera* would be destroyed, is shown by Dr. Werneck to be decided. He also has discovered the anus in *Bodo grandis, Prorocentrum micans, Cyclidium Glaucoma,* whereby the family of *Pseudopoda* only would remain without an alimentary canal. But he has also seen in a *Navicula* (*undulata*) among the Bacillaria group, a convoluted canal, which he considers as the alimentary tube, filled with infusoria. Most interesting are the representations (Dr. Werneck's) of many varieties of intestinal canal with their sacculi or globular pouches or recesses, which present exactly the same appearances as those laid before the Academy in 1830, but lately denied by Prof. Rymer Jones and Meyen after imperfect examinations."

I shall now make some observations on the various statements I have enumerated, and point out in what particulars they disagree with my own experiments. In the first place, as regards our not being able to *see* the alimentary tube, this I cannot imagine to be any impediment or ground for our disbelieving its existence. Doubtless the whole substance of the gelatinous bodies of these minute beings is very elastic, and the walls of the tubes in which the alimentary matters are conveyed are always in apposition except when alimentary matters separate them. The outline of the intestine in many of the Infusoria depicted by Ehrenberg has been, without doubt, drawn from the course which that illustrious observer has noticed the granules of colouring matter and food to take. In fact, he says, "In many this direct observation is impossible, although the result, viz. the colouring of the filled stomachs, is evident†." The solid particles cannot arrive at the sacs in which they are contained and accumulated without passing through some communicating canal; this canal is part of the intestinal tube. The minute alimentary particles which arrive in the sacs entire could not be conveyed in that state by solution and imbibition. Moreover we cannot, I think, wonder at our not being able to detect the walls of the tube; first, because, as I have previously mentioned, the elasticity of the substance of the animalcule would keep the walls in contact except where actually distended; and secondly, the minute size of such a canal, and our being obliged to view it through the substance of the animalcule which intervenes between the sacculi and the upper surface of their bodies as lying under the field of the microscope, is well calculated to prevent this. Could we make a delicate transverse section of their bodies, we might then perhaps be able to perceive the tube. M. Dujardin's objection to the existence of an intestine in Infusoria, "that no fibres remain when the animal is decomposed by diffluence," is undoubtedly futile; it must indeed require a subtle imagination to expect we can see or even contemplate the size of the fibres of the intestine of the Polygastrica, whose diameter, did they exist, must be almost beyond the power of calculation, much more of vision. That the masses of colouring matter which have been received into the sacculi revolve or circulate, as it has been called, is a truth which is very readily proved. Currents are established by the oral cilia; particles floating or suspended in these currents are drawn into the mouth of the minute creature, these then enter the body one at a time, and apparently accumulate in one of the sacs (*i. e.* really accumulate in the upper portion of the alimentary tube); this then moves down one side of the animalcule; others are filled in the same manner. The circulation, as it has been called, of these alimentary boluses may then, after having been distinctly followed down one side, be seen returning in an ascending direction. In some cases when these masses have arrived near the oral extremity they can be detected approximating the depression by which they entered, until at last their contents are gradually ejected; when the masses are solid, this ejection often takes place particle by particle; when in the liquid or semifluid state, in a fine stream; the sac can be seen emptying itself of its contents; it then disappears. In some of the animalcules this movement of particles may be very readily detected; it is very tardy in others, and seldom visible at all times. The addition of reagents to the liquid in which they live produces effects somewhat similar to vomiting or purging; the motion of the alimentary boluses is increased, and their ejection is easily viewed; weak solutions of potash or æther produce this effect. Now in all these cases of movement I am convinced that it is not the sacculi or stomachs which move: we must recollect the sacs are made visible to us by their contents, and in many cases there are no stomachs visible when they are empty, and it is their contents which we see circulating or moving in their proper canal or alimentary tube, and not the sacculi themselves. The motions of these masses may not inaptly be compared, but merely for the sake of illustration, to those of the alimentary masses in our own intestines; the revolution of these (if viewed under similar circumstances) would produce the appearance of circulation; when the masses have arrived at the termination of the canal they are ejected, but here the portion of tube or stomach is not ejected. This comparison exemplifies to my mind the true nature of the sacs in the Infusorial Polygastrica.

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* Bericht über die zur Bekanntmachung geeigneten Verhandlungen der Königl. Preuss. Akademie der Wissenschaften zu Berlin, im Monat Februar 1841.

† Die Infusionsthierchen als vollkommene Organismen, page 2.

We certainly cannot admit, as in the explanation of Prof. Ehrenberg, that the rotation of the globules or balls of alimentary matter takes place in a cavity formed from a distended portion of the alimentary tube. We see this rotation when the intestinal tube is very slightly distended and when the balls of food are very small; but I believe it to be capable of explanation in the manner I have stated; the appearance of one of the sacculi when really distended is so readily recognised that it could hardly be mistaken; but the stomachs (*i. e.* their contents) have been seen to rotate, by observers, when neither the animalcule nor its stomachs are at all distended; and undoubtedly this is a real rotation, not an optical illusion from any peristaltic action. Moreover the rotation of these bodies is so constant as to be considered as their *ordinary* state; whereas, did it arise only in distended states of a stomach or the alimentary tube, it would be rare, or at least only to be seen when the animalcule takes in a large portion of aliment; and I think that any one who has distinctly seen (as I often have) various floating alimentary particles taken in at the oral orifice separately, then accumulating into a small ball, and this ball descending in the body of the animalcule, and "circulating" as I have described, will be convinced that this explanation is correct.

I cannot believe they are recesses from a common tube; I have never been able to detect a horizontal or retrograde course which would be pursued by the boluses, were such the case. The alimentary canal is most commonly in a convoluted form, or coiled; and there is doubtless a difference in the extent and arrangement of the tube in those which feed upon other animalcules and those on vegetable matter. The fact of the portions of food contained in their sacculi being gradually approximated to the surface of the depression, and there being separately emptied, is, I think, a clear conviction that there can be no single stomachal cavity, and also, that the rotation of particles does not take place in a single dilated tube. Moreover it must be recollected that the different portions of the intestinal tube or sacculi are not stained, they are coloured from their cavitary contents, their walls are colourless. M. Meyen's opinion concerning the cilia I have not been able to verify; but the rolling up of the alimentary matters, whereby these masses rotate on their axes, is never to be seen. The account given by Mr. Addison concerning the action of liq. potassæ is, as has been observed, very remarkable. The best mode for the observer to perceive the true effects of potassa on the Polygastrica is to use it slightly diluted, for when used of the strength of the ordinary liquor potassæ, the effect takes place so suddenly as to lead to the inaccurate interpretation of the appearances that gentleman has given. The effect of the addition of this reagent, is solution of the external covering of the animalcule, whereby the internal elastic parts of the body, being liberated from the compression of the external tunic, at first rush out, but are soon dissolved in the same manner, when the alimentary matters remain. This phænomenon is the result of the chemical action of the potash on the substance of the highly elastic animalcule, most certainly not of any imbibition or endosmosis. What are the conditions of the fluids requisite for the production of this physical phænomenon? Difference in their density; the liquid in the cavity towards which the fluid flows must be the most dense. The cavity of the body, supposing such to exist, must contain a fluid of greater density than that in which it floats or is suspended; in most of these Infusoria it is so at all times, and their medium * being of extremely low specific gravity, almost equal to that of distilled water, the most favourable conditions for the action of imbibition are combined; yet no endosmosis and consequent bursting takes place. But we are told that when solution of potash, a liquid of much greater density than that of the medium in which these minute atoms are immersed, is added to their ocean, imbibition does take place, their bodies burst; whereas we have added the conditions requisite for the opposite effect, viz. that of exosmose, and that this does not occur, the "bursting" of the body of the animalcules proves. I believe the greater part of the confusion which has existed on this subject has arisen from considering the alimentary matters in different portions of the intestinal canal as the dilated portions of that canal themselves. That these particles (stomachs) are cells which float in the fluid of the body and elaborate the materials for its nutrition, in the same manner as do those of the chyle and blood of higher animals, may certainly be correct, but we have not the slightest evidence of any analogy between them. The globules of the blood and lymph are contained in those fluids, from whose

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* I allude to the water in which they ordinarily exist.

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